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GRAIN STORAGE PROBLEMS AND INVESTIGATIONS

by

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This paper discusses primarily the engineering phases of the more important problems of grain storage and of studies which have been conducted during the past two years by the Bureau of Agricultural Chemistry and Engineering in cooperation with some of the state and other Federal agencies. Reports covering a large part of the previous investigations of wheat and corn storage are published in the form of Department circulars and articles in the Agricultural Engineering Journal.[1] Additional projects have been added within the last few years. About two years ago, a Bankhead-Jones project on Grain Sorghum Storage was initiated with a field station at Hays, Kansas. This is cooperative with the Bureau of Plant Industry, the Agricultural Marketing Service and the Kansas Agricultural Experiment Station. More recently a new project on methods of properly caring for grain in long time storage was begun. The funds for this project are supplied by the Commodity Credit Corporation. Several Federal and State agencies are cooperating on this project. These include the Commodity Credit Corporation, the Agricultural Adjustment Administration, the Bureau of Agricultural Chemistry and Engineering, the Bureau of Entomology and Plant Quarantine, the Bureau of Plant Industry, the Agricultural Marketing Service, and State Agricultural Experiment Stations in North Dakota, Kansas, and Iowa. Regional headquarters for this project are at Ames, Iowa, with field stations at Hutchinson, Kansas, and Jamestown, North Dakota.

Wheat Storage Studies

Although storage studies have been conducted during the last several years at several field stations under a Bankhead-Jones project, the problems of the storage of wheat over several years have not been covered by this project. In anticipation that new problems would be encountered by long time storage on farms, the Commodity Credit Corporation has supplied funds for careful planning and detailed observations in connection with two experimental wheat storage sites. One of the sites selected is at

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1. A list of publications is appended at the end of this paper.

Hutchinson, Kansas, which is in the hard winter wheat area, and the other is in the spring wheat area at Jamestown, North Dakota. The Corporation has also made available steel bins and wheat in its possession. The erection and filling of these bins, involving the erection of about 340 bins and the placing in storage of about 600,000 bushels of wheat, were begun in June 1941 at Hutchinson and completed the latter part of August. At Jamestown, the work of erection and filling was about a month later.

The studies at each of the two locations consist of four parts or divisions, namely: (1) management studies, (2) floor studies, (3) ventilation studies, and (4) special studies. The field work, including the procuring of samples, observing temperatures, fumigation of bins and analysis of data is a joint obligation of the Bureau of Agricultural Chemistry and Engineering and the Bureau of Entomology and Plant Quarantine. The Agricultural Marketing Service makes all determinations of grade and all fat acidity, protein, germination, and milling and baking tests. The Agricultural Adjustment Administration through its county associations in the counties in which the two sites are located makes all arrangements for the wheat and takes care of many other matters incidental to the project. The Agricultural Experiment Stations of Kansas and North Dakota cooperate by providing any assistance needed and by furnishing equipment and technical advice.

A brief description of each part of the studies is given below:

Management studies: These are designed to permit the evaluation of different types of treatment and conditioning practices as well as to determine what types of structures will be most effective and economical in keeping wheat in good condition over a period of several years. The influence of high dockage and of low test weight on the ability to keep wheat in good condition is also to be determined. Management studies apply to about three-fourths of the wheat in storage at each site and the greatest amount of effort is therefore extended in this direction. The accompanying table gives the number, the size and the types of bins and the kind of wheat to be placed in each group of bins and the treatment to be applied or the conditioning practice to be followed at the Hutchinson Site. Essentially the same plan is followed at Jamestown, except that large bins are not used and Durum wheat is used as well as hard spring wheat. Also a few modifications are made in the treatments to fit the conditions of that area. The conditioning methods may be considered as being of two different groups or classes, namely: those which are preventive and those which are curative. Bins of three different sizes are used to learn what storage difficulties may be encountered and to determine what the possibilities are for reducing the cost by increasing the size of bin. The large bins at Hutchinson have been supplied on a loan basis by several steel bin manufacturers in the interests of these studies.

Bins have been made with different degrees of tightness by caulking walls, floors and even roofs, which is for the purpose of determining the merit of tightness for not only keeping out moisture but also for the control of insects.

Both perforated and solid 18-inch central tubes have been installed in a number of 2740-bushel bins. The bottom of the tube is connected to outside air by a horizontal duct running from the center of the bin to the door. The solid tubes are intended to perform only the function of cooling the wheat. The perforated tubes permit a limited amount of aeration as well as cooling. It is planned to have the ventilators open during cold weather and closed during warm weather.

All of the wheat used for these studies is of the 1940 crop. The wheat at Jamestown had been stored for one year in surrounding country elevators and that at Hutchinson in local terminal elevators. In general, the wheat in all bins at each location runs about the same in moisture content and other grade factors; however, at both Hutchinson and Jamestown several bins are filled with wheat of low test weight and several with high dockage wheat.

Samples for grade, milling and baking, fat acidity, germination and protein tests are being taken periodically and close watch is kept upon insect activity by the entomologists. Thermocouples are being installed in each bin and it is planned to make temperature observations every two weeks. Complete records of the cost of the various treatments, such as fumigation, turning, and cleaning are also being obtained, and we feel that from these data it will be possible to draw definite conclusions as to the best and most economical method of storing wheat in farm size structures.

Floor studies: In view of the lack of information on floors suitable for grain bins, a total of 13 different types of floors and floor treatments are being observed at each station in 1000-bushel bins. The different types are as follows:

1. Steel floor laid over earth fill.
2. Same as "1" except gravel fill.
3. Same as "1" except floor laid over hollow masonry blocks.
4. Steel floor laid over wood joists set up off the ground.
5. Concrete floor laid over earth fill.
6. Same as "5" except gravel fill.
7. Same as "5" except floor laid over hollow masonry blocks.
8. Same as "5" except overlaid with a layer of moisture-proof paper.

9. Same as "5" except overlaid with 1-inch wood boards.
10. Same as "5" except overlaid with both moisture-proof paper and 1-inch boards.
11. Same as "5" except asphalt applied hot and topped with 1-inch concrete.
12. Single wood floor set up off ground.
13. Double wood floor set up off ground with layer of moisture-proof paper between.

Each of the types is studied in duplicate at both Jamestown and Hutchinson.

A special probe is being developed to permit taking samples of grain in contact with the floor without emptying the bin. In this way, continuous observation of the condition of the grain next to the floor can be made over an extended period.

Ventilation studies: In view of the need for methods of conditioning damp wheat on farms, some of the more promising methods of bin ventilation are being tried at both bin sites in order to determine more nearly the limitations of each method. For example, at Hutchinson, the methods being tried are as follows:

Wind pressure cowl with central chamber	3 bins
Perforated floor with pressure cowl	2 bins
Mechanical ventilation (day only)	2 bins
Mechanical ventilation (continuous day and night)	2 bins
Check (Tight floor and walls)	3 bins

Only 1000-bushel bins are being used for these studies. Wheat from the new crop, with excess moisture, was placed in these bins. However, it was not possible to fill all bins with damp wheat of the same moisture content. At Hutchinson, tests on the mechanically ventilated and the check bins are already completed. These were filled with wheat of nearly the same moisture content ranging from 14.7 to 15.4 per cent. The wheat in the check bins went out of condition after less than two months storage. That in the mechanically ventilated bins dried to a reasonably safe moisture content within two weeks.

Special studies: Some of the bins at both Hutchinson and Jamestown are being used for special studies having to do largely with insect control by fumigation, by using insect repellant covers over the grain to prevent infestation from the outside, and by special turning and cleaning methods. The value of different types of bin covers, such as waterproof paper and cotton bats, which are laid directly on the wheat, for controlling both insect infestation and moisture accumulation and re-distribution, is being studied at both stations. Two bins with dome roofs

of the type used on silos, but so reinforced as to resist the outward pressure of the grain when filled to within 4 feet of the top, were erected at Jamestown and are being tested for strength, weathertightness, ease of sampling and filling, and cost of storage per bushel. A bin painted white is being studied at Hutchinson to determine whether the wheat in the painted bin will average lower in temperature than that in the unpainted, and whether the difference in temperature will affect the wheat quality in any way.

Corn Storage Studies

Investigations relating to corn storage during the past two years have been in the form of (a) a field survey of farm storage of ear corn, (b) storage of both ear and shelled corn in experimental cribs and bins, and (c) observations of shelled corn in steel bins owned by the Commodity Credit Corporation. Under the new project being supported by the Commodity Credit Corporation the observations of shelled corn in steel bins have been expanded considerably this fall (1941).

Ear corn storage: Field inspections of cribs in several counties throughout the Corn Belt have shown that cribbing corn with too much excess of moisture is hazardous even if the crib is considered to have more than the usual amount of ventilation. In northeastern Iowa some of the corn being placed in cribs in the fall of 1940 contained moisture in excess of 25 per cent. An unusual amount of corn became moldy the following spring. The corn in many cribs was disposed of or moved to prevent further damage. In almost every case the damage was due to excess of moisture. This was true even in cribs considered to be satisfactory for drying out corn of more than the usual moisture content.

Samples obtained periodically from cribs containing corn from the 1940 crop in northern Illinois showed marked differences in drying in different types of cribs. In general the corn in single cribs not more than 8 feet wide which were well exposed dried most rapidly. The corn in octagonal cribs, the diameters of which were from 14 to 16 feet dried the least and contained the greatest amount of damage.

Within the last few years a few cribs provided with the same ventilation features as those used in bins for the conditioning of high moisture wheat have been developed. These have been under observation at the Agricultural Engineering Research Farm, at Iowa State College.

Observations on the performance of two types of circular cribs employing different methods of ventilation are worthy of comment. The one type is referred to as "wind pressure" or "downdraft" ventilation. It has a rotating cowl which faces the wind and is

joined to a large central flue. The air passes into the cowl down the flue, through the corn and out through the wall. The other type has a suction rotating cowl and may be referred to here as "updraft" ventilation. The air is simply drawn up through the perforated floor and the corn, and then exhausted through the cowl. Further detailed descriptions of each crib are given in the following table:

Reference Symbol	Shape	Type of Ventilation	Diam. or Width	Height	Capacity	Floor	Wall
A	Cir.	Wind Pressure	14 ft.	8 ft.	500 bu.	Perf.	Wire Cribbing
B	Cir.	Wind Pressure	18 ft.	11 ft.	1000 bu.	Solid	Perf.
C	Cir.	Suction	14 ft.	8 ft.	500 bu.	Perf.	Solid*
D	Cir.	Suction	14 ft.	11 ft.	500 bu.	Vent.	Solid
E	Rect.	None	6½ ft.	8 ft.	500 bu.	Vent.	Perf.

* Solid with exception that lower 2 feet are perforated.

Cribs A and B are equipped with ventilators of the wind pressure type and C and D with ventilators of the updraft type. Crib E is a narrow rectangular crib which has been included here for comparison purposes.

The accompanying figure shows the observed average moisture contents of samples taken periodically from different parts of each of the different cribs through the winter and through the drying period in the spring. The daily observed moisture contents of individual ears of corn fully exposed to air is also shown for this same period. This serves as a basis for comparing the performance of the different cribs. It will be noted that the moisture contents of the corn in cribs A, B, and E are about the same towards the end of the storage period and approach the moisture contents of the exposed ears. The corn in cribs C and D having ventilation of the updraft type dried slowly. The corn in crib C which was placed in storage with a moisture content of 20.5 per cent actually increased in moisture content. This was due to the absorption by the kernels of moisture from the cobs, a condition which has been observed to occur in parts of the crib where ventilation is poor.

While some drying occurred in the spring, it was not sufficient to prevent the corn from spoiling.

On the basis of average moisture content the drying performance of the cribs provided with wind pressure ventilation was very nearly equal to that of the rectangular crib E, 6½ feet in width, and with regard to corn in the center of the crib the former was superior.

The results with wind-ventilated cribs indicate that unusually good performance in the drying of high moisture ear corn can be obtained in circular cribs which are otherwise considered to be inferior to rectangular cribs. The action of the wind on a circular structure is such as to create suction over three fourths of the wall. By supplying air in the center of the crib under a positive pressure, greater heads or pressure differences are obtained to create air movement through the ear corn.

Shelled corn storage: Observations have been made periodically on dry shelled corn in storage on farms and in steel bins owned by the Commodity Credit Corporation. With the aid of funds supplied by this agency, observations now are being made on about 100 bins located in different areas of the Corn Belt. Samples for grade, fat-acidity, and germination tests and insect counts are taken regularly. The last are made by State Entomology Departments and the Bureau of Entomology and Plant Quarantine. Temperatures in different parts of the bins are to be observed regularly about once a month.

The observations to date have shown that the storage of dry shelled corn is generally successful, provided the corn does not have a moisture content greater than 13 per cent, is relatively free from insects, and provided no water leaks into the bin. After two years of storage, the top layer of corn, about a foot in thickness, appears to be in the poorest condition. The greatest increase in damage is found in this layer, largely because of an increase in moisture during the fall and winter. However, with the coming of warm weather in the spring, the layer dries out again.

During the turning and cleaning of corn in steel bins, a splendid opportunity was provided for observing the condition of corn in different parts of the bins. The junction of the bin floor and wall, which is simply a lap joint, is faulty in that it admits sufficient moisture to spoil the adjacent corn. While on the whole such spoilage has not been more than a bushel and often less, such a condition has made the corn conducive to the development of insects. This emphasizes the importance of having bin walls and floors made tight to prevent any ingress of moisture even in the form of vapor.

Field shelled or combined corn with a moisture content of 17.5 and 21.0 per cent was stored in two wind pressure ventilated steel bins in connection with the experimental studies of bins and cribs. These were of the same type as those used with success in the storage of high moisture wheat and grain sorghums. Although the moisture content of the corn in the two bins was reduced to approximately 16 per cent by the latter part of April, corn in certain parts became musty and it was necessary to remove all the corn to prevent further deterioration. While this type of ventilation was rather successful with wheat and grain sorghums, its limitations as to the maximum moisture content at which corn can be conditioned successfully under conditions common to the Corn Belt remain to be determined by further trials.

Grain Sorghum Studies

Grain sorghums are becoming increasingly important feed crops, particularly in Kansas, Texas and Oklahoma. Since the crops mature rather late in the fall, they usually contain considerable excess moisture unless the weather conditions have been favorable for drying throughout the greater part of the fall. The drying of grain sorghums in ventilated bins is difficult because the weather conditions in late fall and winter are poor, due to lower temperatures and higher humidities.

In 1939 a study of grain sorghum storage, supported by Bankhead-Jones funds, was begun at Hays, Kansas. This project was conducted cooperatively by the Department of Agriculture and the Kansas Agricultural Experiment Station. Several different types of both natural and power ventilation systems were observed. A partial report of the results has been given in "Agricultural Engineering" by Fenton.[1]

The study is to continue on the same basis as in the past with the exception that experimental storages are to be set up at Hutchinson, Kansas, where the experimental bins which have been used for conditioning high moisture wheat can be made available for use in conditioning grain sorghums containing excess moisture.

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1. Storage of grain sorghums. Agr. Engr. Journal. May, 1941.

Published Reports on Grain Storage Investigations

1. "Methods of drying grain on the farm", by C. F. Kelly. Agr. Engr. Jour. April, 1939.

2. "Results of research in corn storage", by H. J. Barre. Agr. Engr. Jour. June, 1940.

3. "Research work in wheat storage", by C. F. Kelly. Agr. Engr. Jour. December, 1940.

4. "Drying artificially heated wheat with unheated air", by C. F. Kelly. Agr. Engr. Jour. September, 1941.

5. "Methods of ventilating wheat in farm storages", by C. F. Kelly. U.S.D.A. Cir. 544. April, 1940.

6. "Temperatures of wheat in experimental farm-type storages", by C. F. Kelly. U.S.D.A. Cir. 587. February, 1941.

7. "Grain storage on the farm", by T. E. Long and M. G. Cropsey. N. Dak. Agr. Expt. Sta. Bul. 302. June, 1941.

COMBINATIONS OF TREATMENT, TYPE OF WHEAT, VENTILATION, SIZE AND TYPE OF BINS IN MANAGEMENT STUDIES AT HUTCHINSON, KANSAS

Treatment	Wheat Type (1)	2740-Bushel Bins					1000-Bushel Bins	Large Bins	
		Tight floor and walls	Tight floor	Tight floor walls and roof	Solid L-tube	Perforated L-tube	Tight floor and walls	L-tube	Tight floor and walls
1. No treatment, no initial fumigation	a	3							
Preventive									
2. No treatment after initial fumigation	a	3		3	2	2	2		
3. Oil spray, June and September	a	3			2	2	2		
4. Fumigation, June and September	a	3			2	2	2		
5. Turning in January	a	3			2	2	2		1
Curative									
6. Fumigation when necessary	a	3	2		2	2	2	1	1
	b	3							
	c	3							
7. Turning and cleaning when necessary	a	3	2				2		
8. Turning, cleaning, and fumigation when necessary	a	3					2		

(1) a. Hard red winter wheat with typical grade factors.
b. Same as "a" except high dockage.
c. Same as "a" except low test weight.